

Effects of pruning of vertical roots on growth of one-year Scots pine (*Pinus sylvestris* L.) seedlings in the first year after transplanting

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ABSTRACT

The research was carried out in 2006 within the area of forest nursery in Okalewo, the Forest Inspectorate Skrwilno (Central Poland, at 53°02'N, 19°23'E). The aim of the study was to determine the effects of root pruning in one-year Scots pine seedlings (*Pinus sylvestris* L.) on their growth after transplanting. The vertical roots of one-year Scots pine seedlings were pruned to the length of 5, 10, 15 i 20 cm and measured. The scope of measurements included: stem length and thickness, total root length, root length within thickness classes, surface root area, root volume as well as the number of root tips and ramifications. The measurements of root systems were performed with the use of a scanner and WinRhizo software. The seedlings were transplanted and were growing in the nursery all through the vegetation season 2006. In October of this year the seedlings were lifted from the ground and measured again at the same scope. Reiterated measurements allowed evaluation of increment characteristics after transplanting. The results indicated negative impacts of intensive root pruning before transplantation on seedling survival rates. Severe pruning of seedling vertical roots had negative effects on increment gained by both above- and underground seedling parts. Pruning roots to 5 cm of length significantly decreased pine seedling survival rate of. On the other hand, 20 cm long roots have no significant effects on seedling survival and increment but they can cause difficulties in seedling nursery cultivation.

KEY WORDS

Pinus sylvestris, seedling, vertical root, transplantation, root system

INTRODUCTION

The root is the underground plant part of the major role in supporting plants in the ground and their life functions such as nutrient and water uptake, gas exchange and vegetative reproduction. Survival and further growth of tree seedlings in forest cultivation are most reliant on

root systems. It is very difficult to evaluate quality of forest seedling roots because much of root systems stay in the ground once seedlings are lifted either manually or mechanically. Seedling roots dry out very fast during nursery technological processes (lifting, storing, transporting and transplanting). At an experimental level there are evaluated features such as the growth potential

(Tarasiuk 1993) or a level of seedling hydration (Wesoły *et al.* 1998). However, the results obtained on these features are of small practical importance. The most often used practical criterion of seedling quality is the length of seedling vertical roots. This characteristic is associated with the operational depth of seedling lifter. It can be assumed that from the practical point of view seedling optimal root system should not be too long and ought to be dense (many expanding small roots). Current quality standards, both Polish and at a European Union level do not include measures of root density. This can be a result of lacking evaluation methods for root density. At the same time available methods (Böhm 1985) are difficult to apply in practice. A new research tool which is WinRhizo software provides prospects for detailed evaluations of the total root length, root length in thickness classes, root surface area, root thickness, root volume as well as the number of root tips and ramifications. The latter is particularly important with regard to density of fine roots. Scanner evaluations are carried out with seedling roots in water thus, have no detrimental effects on seedlings which can still be used as planting material after measurements. The tool allows precise evaluation of root morphological features as well as further assessment of seedling growth after nursery transplanting operations or when in forest cultivation.

The relation between the size of under- and above-ground seedling parts is an important aspect. It is advised that seedling aboveground parts are not too large when compared to the size of seedling root system.

Right after nursery transplanting or at forest cultivation planting, seedling root system should secure supply of water and nutrients to aboveground parts, which is in a straight line dependent on the number of fine roots that form mycorrhizal associations with specific fungi.

In the 1950s, investigations on effects of morphological features of one-year-old pine seedlings were carried out by Kędzierski (1951). The results obtained by this author indicated that bigger seedlings with more lateral stems showed a higher survival rate. However, in this research there were not included observations on seedling root systems, probably due to lack of available methodology for detailed measurements.

METHODS

Observations were conducted in 2006 in the forest nursery Okalewo within the area of Forest Inspectorate Skrwilno (Central Poland, at 53°02'N, 19°23'E) as well as in the laboratory of the Department of Forest Silviculture at the Forest Faculty of the University of Life Sciences-SGGW in Warsaw. Research material constituted one-year Scots pine seedlings (age 1/0) with the height from 7.6 cm to 8.3 cm (mean 7.9 ± 0.4 cm). In April 2006, the seedlings (age 0/1) were manually lifted from the ground and transported to the laboratory. There were 360 seedlings observed, which were divided into 4 groups (3 replications of 30 seedlings). In each of the 4 groups seedlings' vertical roots were pruned to the length of 5, 10, 15 i 20 cm, respectively (Fig. 1).

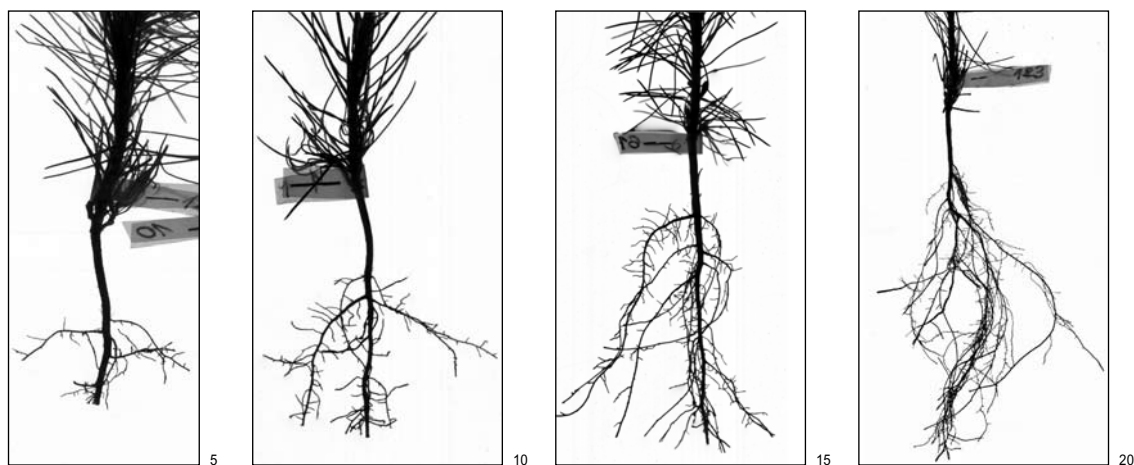


Fig. 1. Seedling root systems of one-year *Pinus sylvestris* seedlings pruned before transplanting to 5, 10, 15 and 20 cm of length

After pruning, the seedlings were permanently marked and their height as well as thickness of root necks was measured. Seedling root systems were scanned in water and obtained data were processed using the WinRhizo software. After measurements, seedling roots were secured against drying out and transported back to the nursery, where they were transplanted in the experimental area following the pattern of 4 variants with 3 replications. The seedlings were growing in nursery conditions all through the vegetation season of 2006.

In October 2006, the survival rate of transplanted seedlings (age 1/1) was determined. Next, the seedlings were manually lifted from the ground and transported back to the laboratory. The seedlings were once again measured (all abovementioned features) using the methods described above. This allowed determining seedling increment after transplantation. Subsequent to measurements the seedlings were dried out at 104°C for 24 h and then dry matter of seedling stems, needles and root systems was assessed.

Scanning of roots and analyses with the WinRhizo software let evaluate a number of root morphological features. In the analyses there were used data on the total root length of seedlings as well as the number of root tips and ramifications. It was assumed that these features could play an important role in seedling adaptation after transplanting.

Obtained data were statistically analysed with the use of ANOVA and the Duncan's multiple range test for determination of homogenous groups (Statgraphics software, STATPOINT).

RESULTS

The average survival rate of seedlings after transplantation was 71.3% (Fig. 2). The lowest survival rate was observed in the group of seedlings with vertical roots pruned to 5 cm of length and the highest (83.3%) was in the group with roots pruned to 20 cm of length.

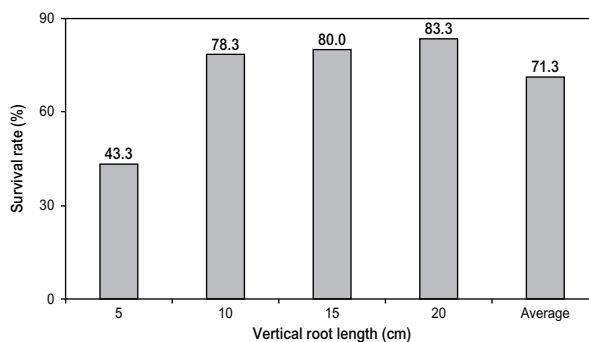


Fig. 2. Survival rate of *Pinus sylvestris* seedlings after transplanting (age 1/1)

For the period of the vegetation season after transplantation significant differences in seedling heights were shown ($p = 0.0413$). The Duncan's test distinguished 2 homogenous groups:

- seedlings with vertical roots pruned to 5 and 10 cm of length
- seedlings with vertical roots pruned to 10, 15 and 20 cm of length.

Absolute seedling height increment after transplantation was from 2.5 to 6.6 cm (Fig. 4). The lowest height increase was observed in the seedlings with ver-

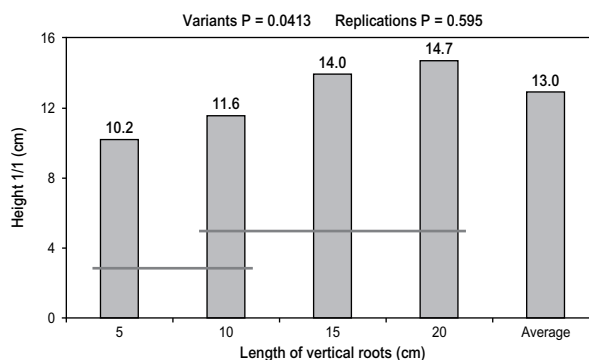
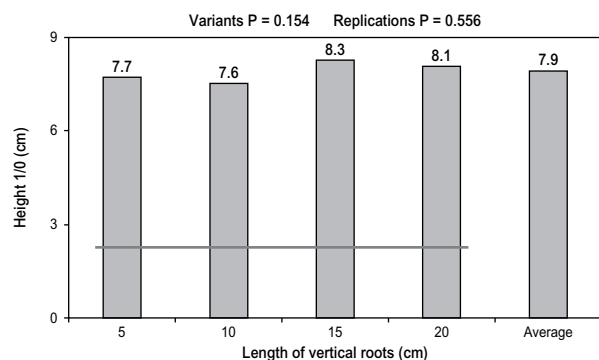


Fig. 3. Height of *Pinus sylvestris* seedlings before (age 1/0) and after transplantation (age 1/1)

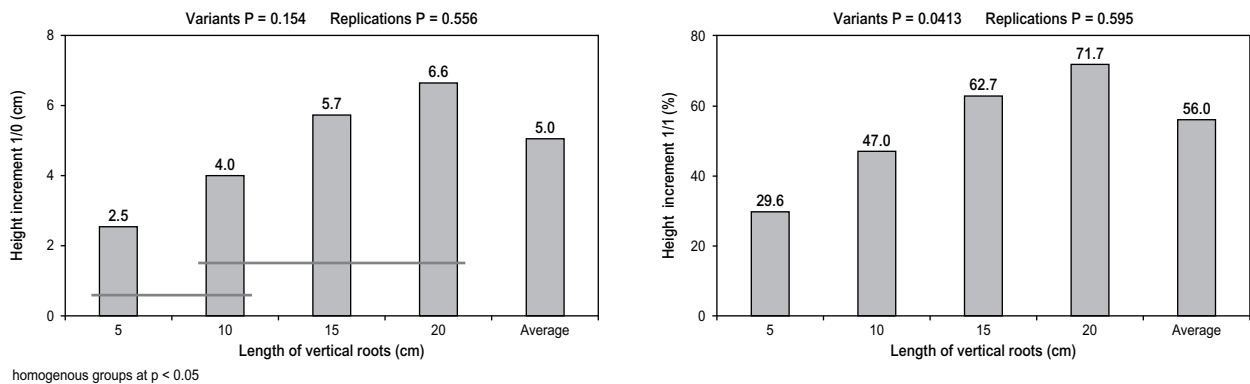


Fig. 4. Absolute and percentage values of height increment of *Pinus sylvestris* seedlings after transplantation (age 1/1)

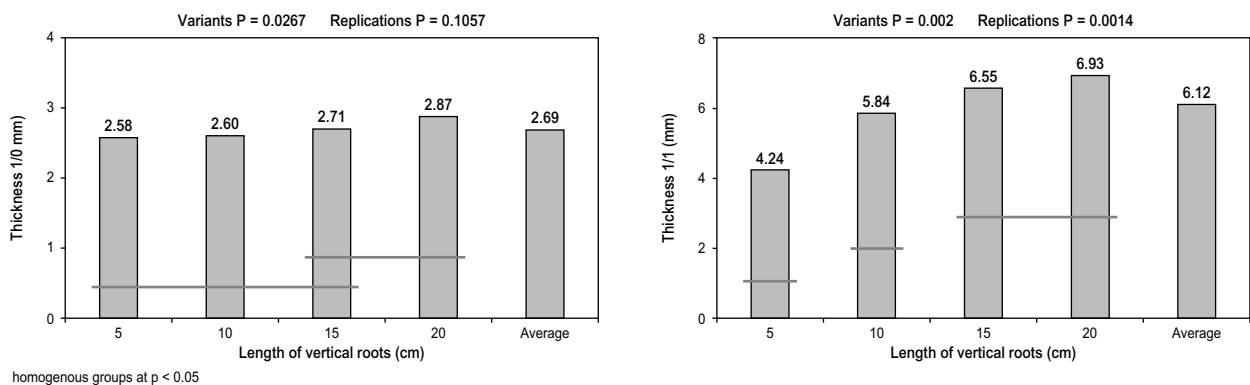


Fig. 5. Thickness of of *Pinus sylvestris* seedlings before (age 1/0) and after transplantation (age 1/1)

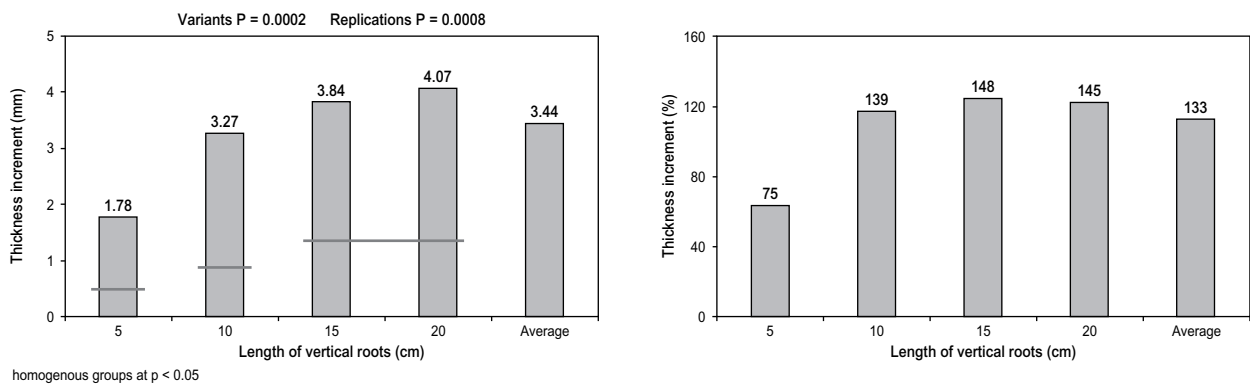
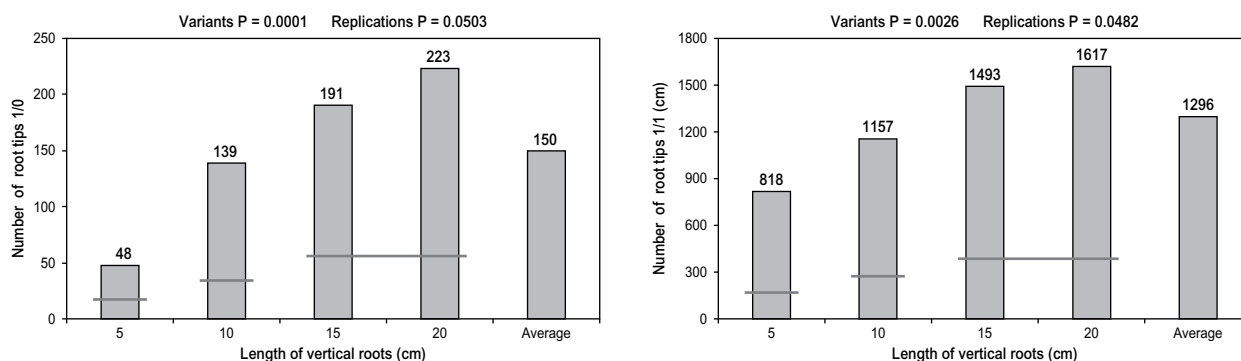


Fig. 6. Absolute and percentage values of thickness increment of *Pinus sylvestris* seedlings after transplantation (age 1/1)

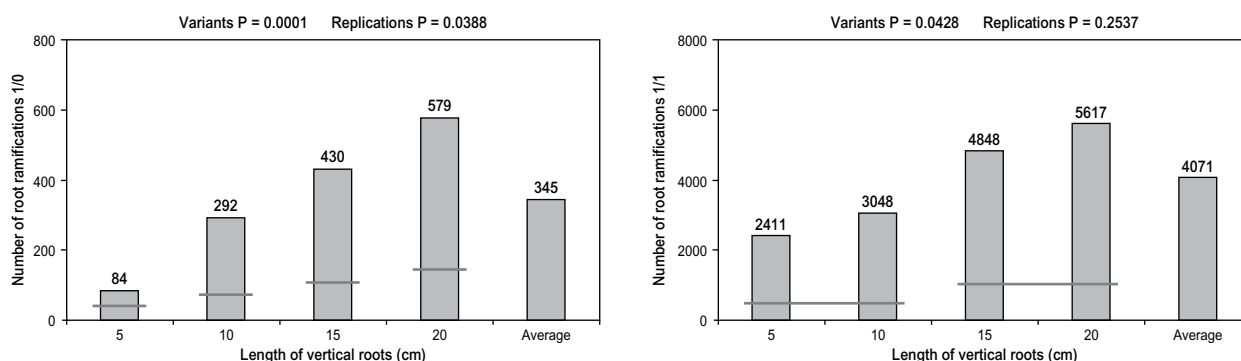
tical roots pruned to the length of 5 cm, and the highest – in the seedlings with roots pruned to 20 cm of length. The observed differences were statistically significant ($p = 0.0405$). Two homogenous groups were distinguished, i.e. seedlings with vertical roots pruned to 5 and 10 cm of length, seedlings with vertical roots pruned

to 10, 15 and 20 cm of length. Height increment after transplantation was directly proportional to the length of pruned roots. Hence, the height of the seedlings with 5 cm roots before transplanting was increased by approximately 30%. In the seedlings with 10 cm roots it increased by 47%, and in the seedlings with 15 cm roots



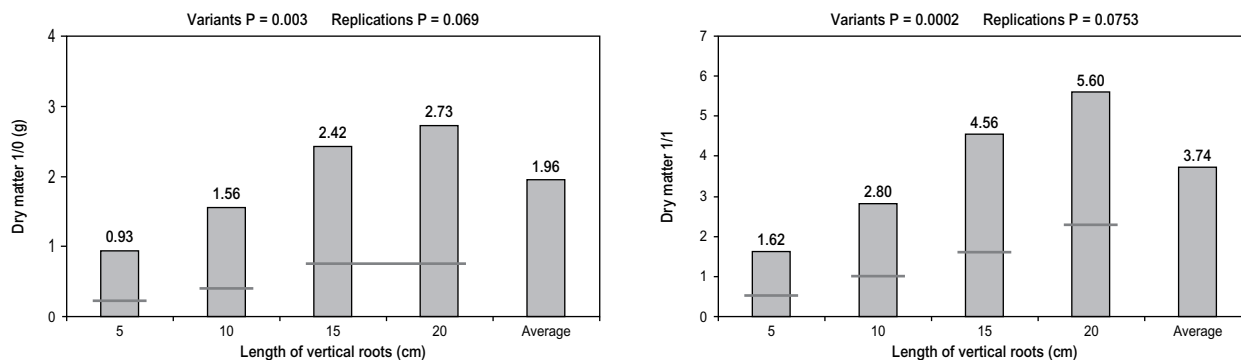
homogenous groups at $p < 0.05$

Fig. 7. Number of root tips in *Pinus sylvestris* seedlings before (age 1/0) and after transplantation (age 1/1)



homogenous groups at $p < 0.05$

Fig. 8. Number of root ramifications in *Pinus sylvestris* seedlings before (age 1/0) and after transplantation (age 1/1)



homogenous groups at $p < 0.05$

Fig. 9. Dry matter of *Pinus sylvestris* seedling stems and needles after transplantation (age 1/1)

it increased by almost 63%. The highest height increment (close to 72%) was shown in the seedlings with 20 cm roots.

After transplantation there was observed high differentiation of seedling thickness at the point of root neck (Fig. 5). The thickness of the seedlings with verti-

cal roots pruned to 5 and 10 cm was 4.24 and 5.84 mm, respectively. The seedlings with root lengths of 15 and 20 cm were 6.55 and 6.93 mm thick, respectively.

Absolute increment of seedling thickness after transplantation was lowest in the seedlings with vertical roots pruned to 5 cm of length. These seedlings

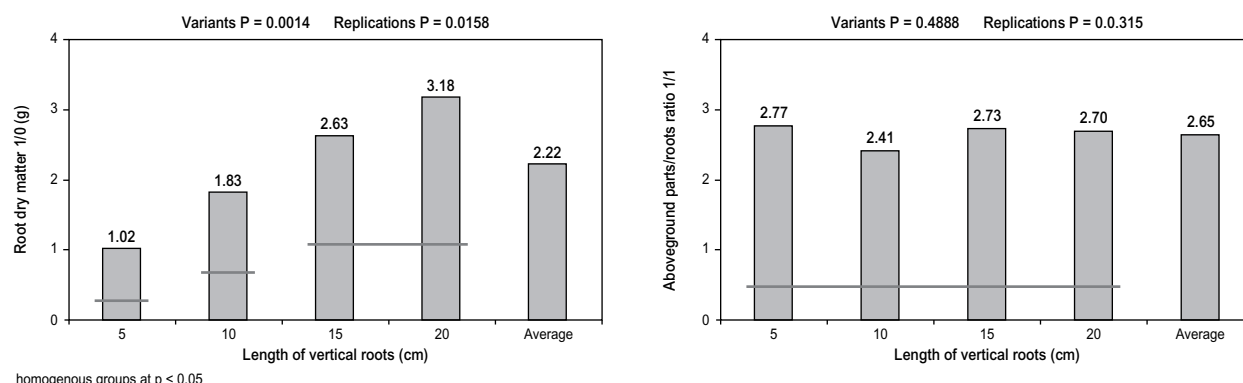


Fig. 10. Dry matter of roots and the ratio of dry matter of aboveground parts to roots of *Pinus sylvestris* seedling after transplantation (age 1/1)

indicated the increase of thickness by 1.8 mm which was approximately 75% of their initial thickness before transplanting. The highest thickness increment was shown in the seedlings with the longest vertical roots before transplanting, i.e. 4 mm which was 145% of their initial thickness (Fig. 6).

The results indicated that pruning of seedling vertical roots resulted in an increase of the number of root tips and ramifications after transplantation (Fig. 7 and 8). In the group of seedlings with 5 cm roots, the number of root tips was 17-fold higher and the number of root ramifications was 29-fold higher. In the seedlings with 20 cm long.

Figures 9 and 10 present dry matter of the seedlings observed. The lowest dry matter of stems, needles and roots indicated the seedlings with 5 cm roots. When compared to these group the seedlings with 20 cm roots showed 3-fold higher dry mass of stems, needles and roots. No statistically significant differences between experimental variants were found for the ratio of dry mass of roots and aboveground parts.

DISCUSSION

The results obtained showed that vertical root pruning before transplantation negatively impacts growth of pine seedlings after transplantation. The survival rate of the seedlings with roots pruned to 10–20 cm of length was at approximately 80% level, while the survival rate of seedlings with 5 cm roots decreased by 43%. In transplanted seedlings, increment of aboveground

seedling parts evaluated by means of measurements of seedling height and thickness depended significantly on the length of seedling vertical roots. Drastic vertical root pruning had bigger effects on seedling thickness than on their height. This confirms the results of other authors on strong relationship between root neck thickness and dry matter of roots (Gorzela 1986, Gunia and Sobczak 1980). Percentage increment of seedling height after transplanting amounted to 29.6% – 71.7%, while seedling thickness increased twice as much, i.e. 76–175%. These results indicate a decrease of fineness indicator expressed by height/thickness ratio in transplanted seedlings.

It can be assumed that the main cause of seedling weakening after transplantation is the reduction of root system which takes place when seedlings are removed from the ground. Most vulnerable in this process are fine roots which are most valuable for seedlings. Small share of fine roots in the root system of the seedlings with vertical roots pruned to 5 cm of length was possibly the main reason of their low survival rate and undersized increment when compared with seedlings with longer roots. In the conditions of this experiment no sprinkler irrigation was applied during seedling cultivation which also could negatively influence the survival rate of seedlings.

At the same time, seedling dry matter – often used as very important measure of seedling quality (Gorzela 1986, Gunia and Sobczak 1980) – indicated big influence of reduction of vertical roots in one-year pine seedlings on their growth after transplanting. The results showed utmost dry mass in the seedlings with longest

vertical roots. However, seedling vertical roots length has to be somewhat constrained because of technologies of planting and transplanting used in forest nurseries. Thus, based on research results it is recommended that the most advantageous length of seedling roots is 10–15 cm. The decision on selection of actual measure for root length can depend on conditions of seedling growth after transplanting and availability of sprinkler irrigation. Shorter seedling vertical roots are more appropriate especially for transplanting if a decrease of seedlings with deformed root systems (e.g. tucked) is required.

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